ECE 322L
Electronics 2

03/03/20- Lecture 12

Biasing the BJT 1

Updates and Overview

- Biasing the BJT (Neamen 5.2 and 5.4, S&S 6.7)

Biasing the BJT

-Biasing: Establishing a Q point for the BJT

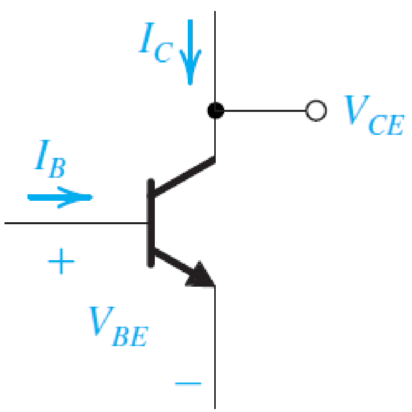
-The Q point is defined by the DC values of the input and output current and voltages. In CE configuration the latter are: I_{CQ}, I_{BQ} (V_{BEQ}), and V_{CEQ}.

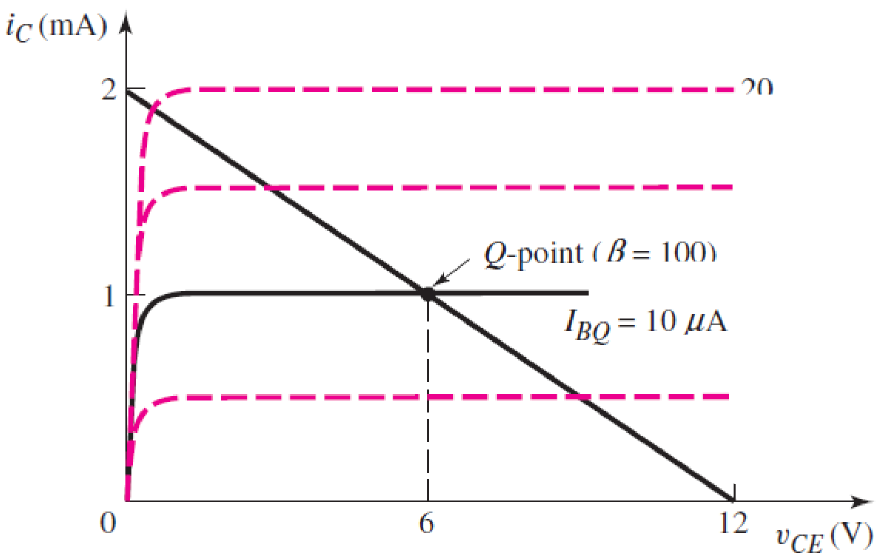
-Desired characteristics of the Q point for an amplifier:

it is in the forward-active region;

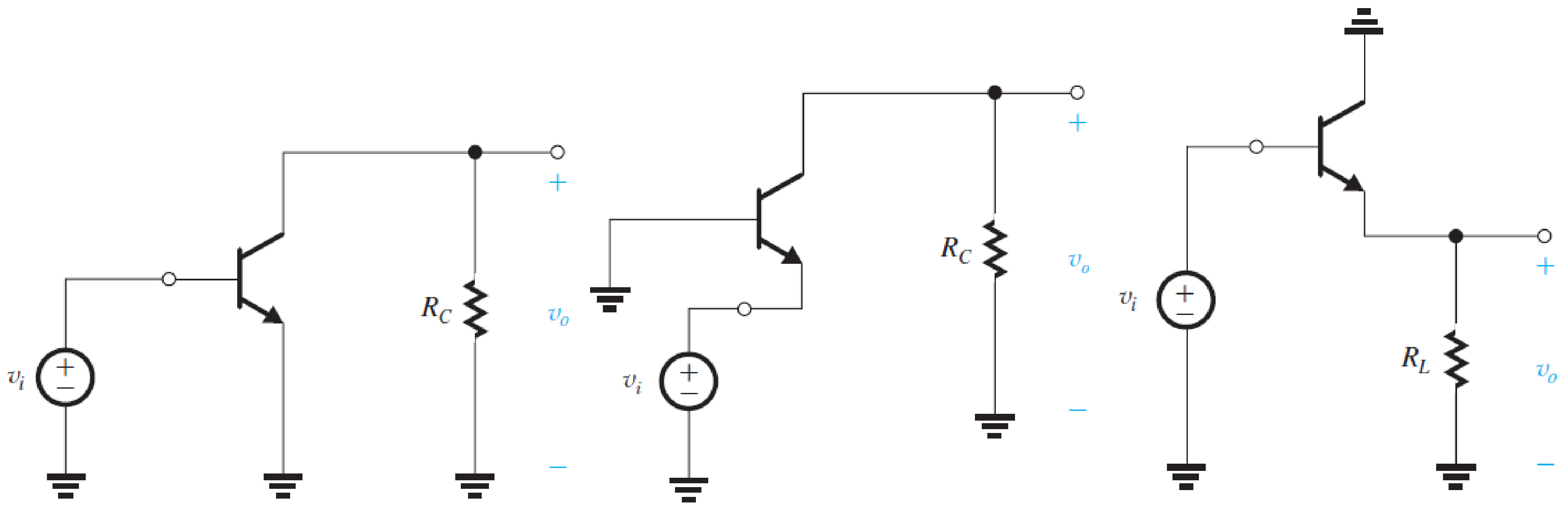
it is insensitive to variations of temperature and β;

it allows for maximum (or required) output signal swing and maximum (or required gain).





BJT amplifier configurations

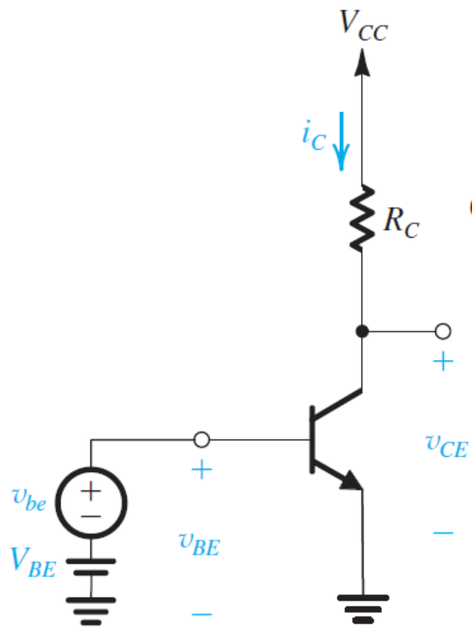


(a) Common-Emitter (CE)

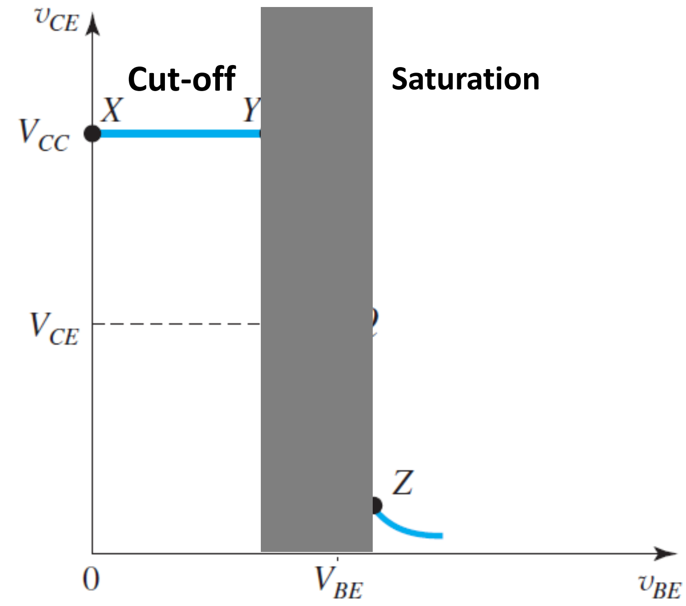
(b) Common-Base (CB)

(c) Common-Collector (CC) or Emitter Follower

Voltage-transfer characteristics (VTC)

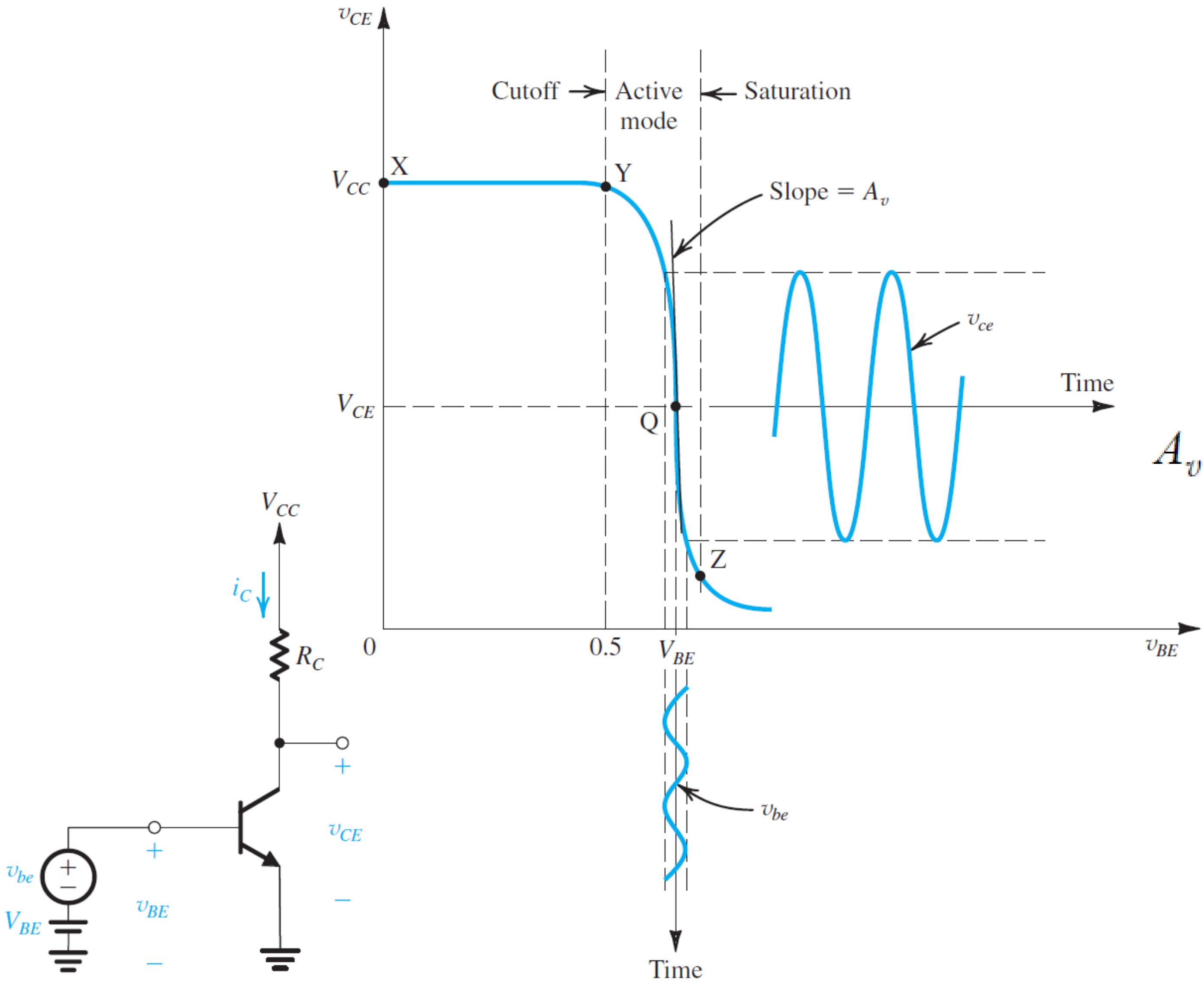


CE configuration



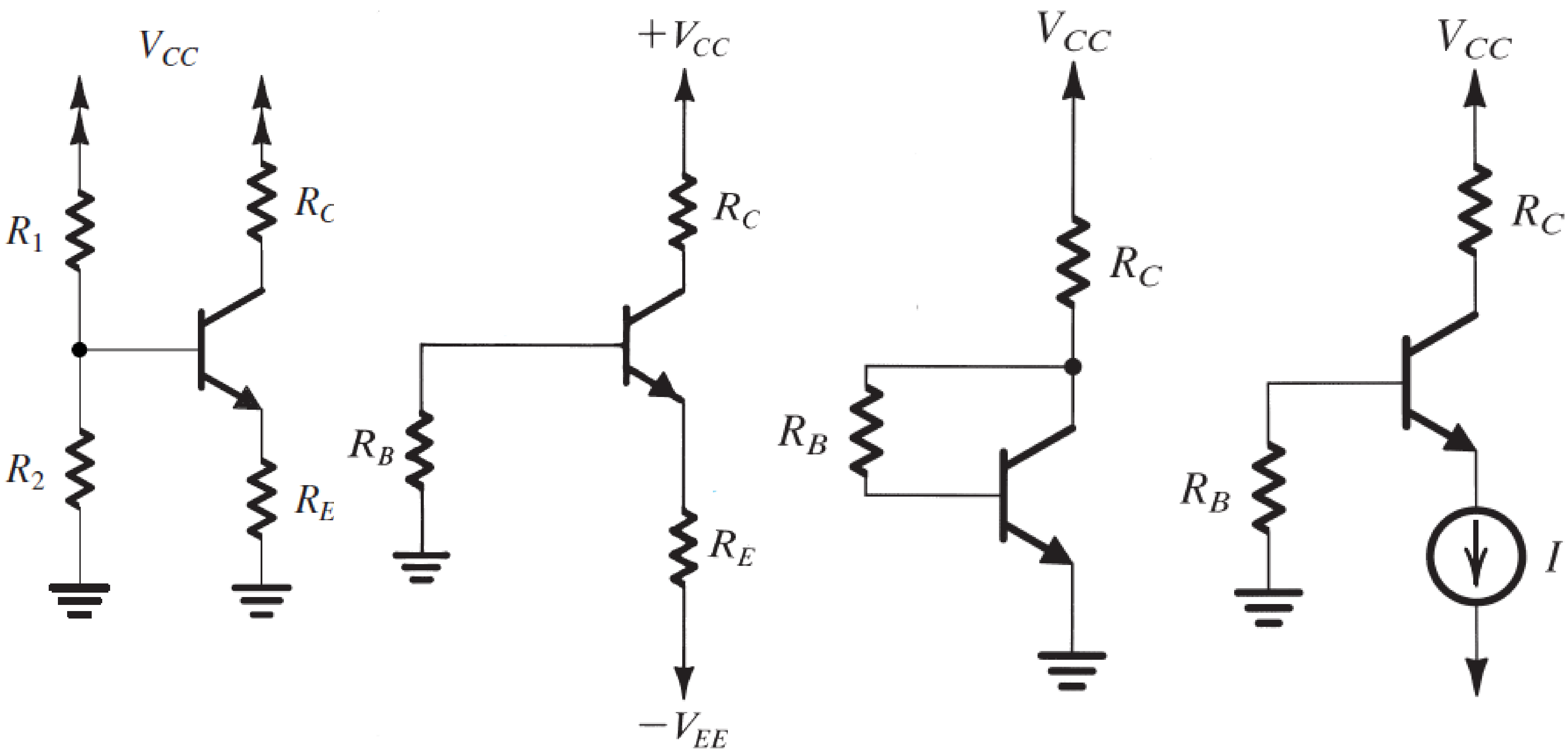
CE configuration: VTC is a V_{CE}-V_{BE} plot
CB configuration: VTC is a V_{CB}-V_{EB} plot
CC configuration: VTC is a V_{BC}-V_{EC} plot

Voltage-transfer characteristics (VTC)

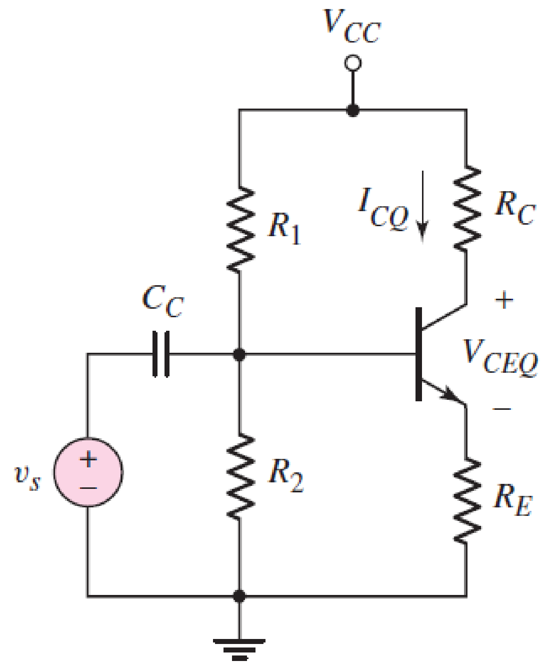


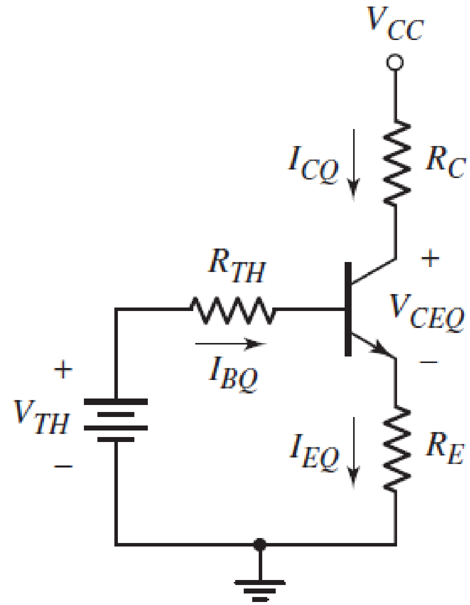
$$A_v \equiv \left.\frac{dv_{CE}}{dv_{BE}}\right|_{v_{BE} = V_{BE}}$$

Biasing configurations



Biasing configurations (1)





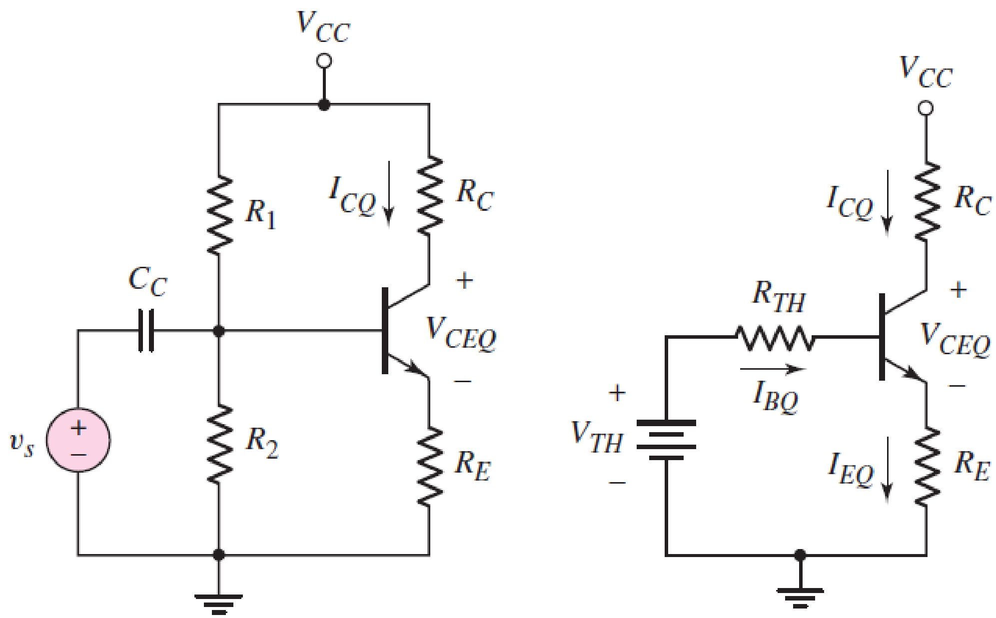
Thevenin equivalent of the voltage divider $V_{TH} = [R_2/(R_1 + R_2)]V_{CC}$ $R_{TH} = R_1 \| R_2$

KVL on the input loop $V_{TH} = I_{BQ}R_{TH} + V_{BE}(\text{on}) + I_{EQ}R_E$

Assuming operation in active region $I_{EQ} = (1 + \beta)I_{BQ}$

$$I_{BQ} = \frac{V_{TH} - V_{BE}(\text{on})}{R_{TH} + (1 + \beta)R_E} \qquad I_{CQ} = \beta I_{BQ} = \frac{\beta(V_{TH} - V_{BE}(\text{on}))}{R_{TH} + (1 + \beta)R_E}$$

Biasing configurations (1)



$$V_{TH} = [R_2/(R_1 + R_2)]V_{CC} \qquad R_{TH} = R_1 \| R_2$$

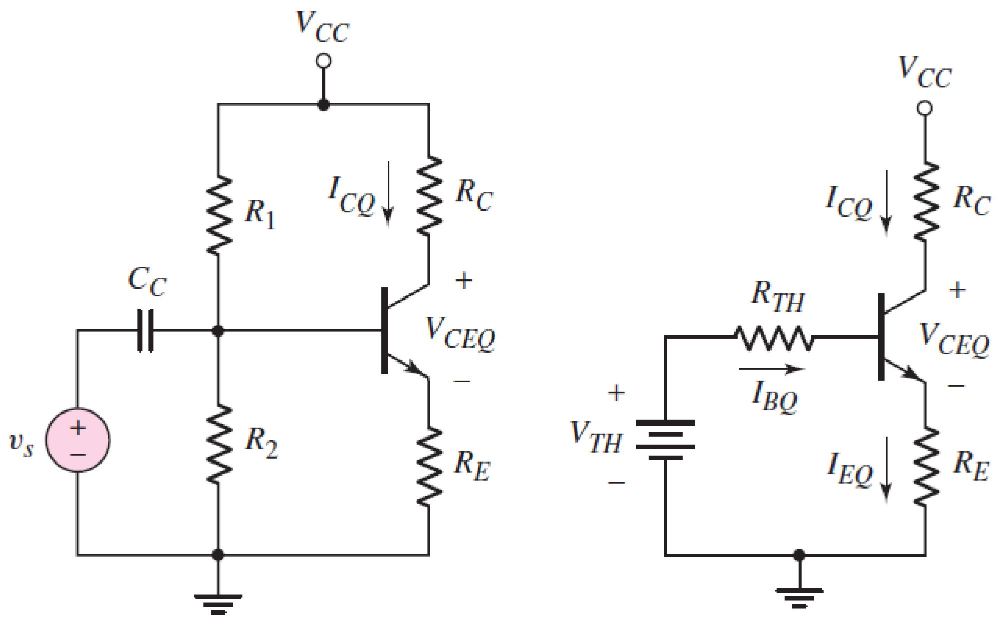
$$I_{CQ} = \beta I_{BQ} = \frac{\beta(V_{TH} - V_{BE}(\text{on}))}{R_{TH} + (1+\beta)R_E}$$

$$R_{TH} \ll (1+\beta)R_E, \quad I_{CQ} \cong \frac{\beta(V_{TH} - V_{BE}(\text{on}))}{(1+\beta)R_E}$$

$$\beta \gg 1$$

$$\beta/(1+\beta) \cong 1 \qquad I_{CQ} \cong \frac{(V_{TH} - V_{BE}(\text{on}))}{R_E}$$

Biasing configurations (1)

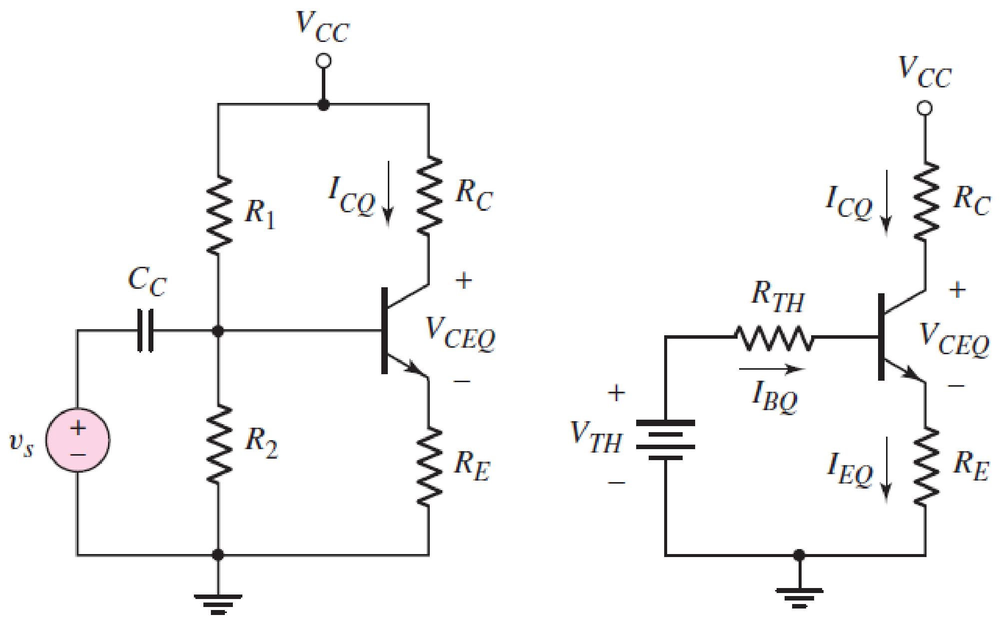


$$I_{CQ} \cong \frac{(V_{TH} - V_{BE}(\text{on}))}{R_E}$$

$V_{TH} \gg V_{BE}(on)$ guarantees stability of the Q point against temperature variation which reflects in a change of the $V_{BE\ (on)}$.

$R_{TH} \ll (1 + \beta) R_E$. guarantees stability of the Q point against variations of β

Biasing configurations (1)



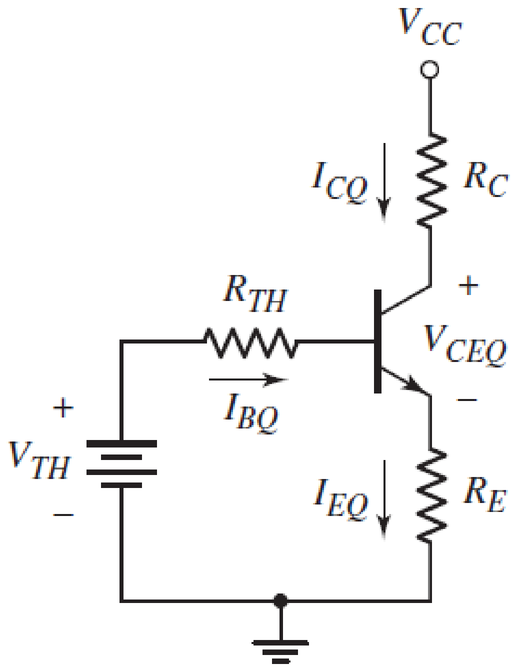
$$I_{CQ} \cong \frac{(V_{TH} - V_{BE}(\text{on}))}{R_E}$$

Mechanism by which R_E stabilizes I_C with respect to temperature:

- Increasing temperature will increase the emitter current.
- Increasing the emitter current will increase the voltage drop across R_E and decrease the V_{BE}.
- A decreasing V_{BE} will decrease the emitter current and the collector current.

Biasing configurations (1)

Examples of trade-off conditions



V_{TH}	Q point	Voltage gain	Output signal swing
High	Stable	Low	Limited by cut-off
Low	Not stable	High	Limited by saturation

R_{TH}	Q point	Input resistance
High	Not stable	High
Low	Stable	Low

Rule of thumb for a Stable Q point in the active region.

$$V_{TH} \cong \frac{1}{3} V_{cc} \qquad R_{TH} \cong 0.1(1+\beta)R_E$$

In-class problem 1

In the circuit shown below, let V_{CC}=5 V, R_E=0.2 kΩ, R_C=1 kΩ, β=150, V_{BE}(on)=0.7 V. Design a bias-stable circuit such that the Q point in in the center of the forward active region.

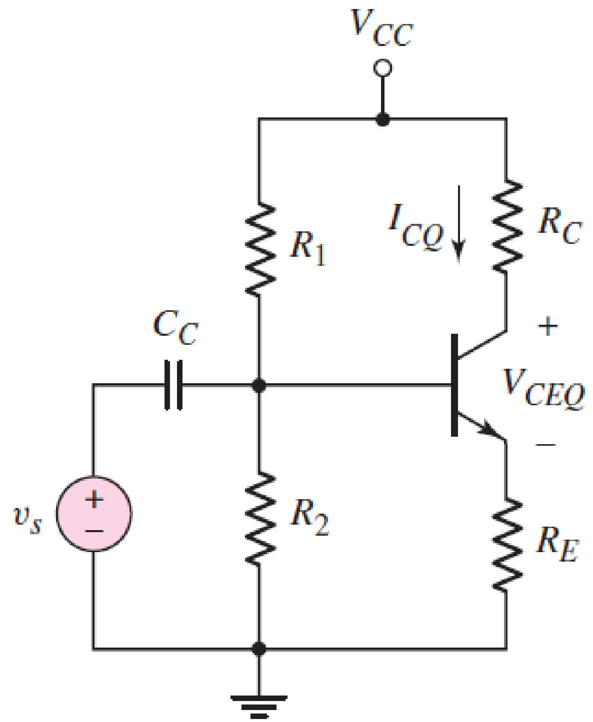
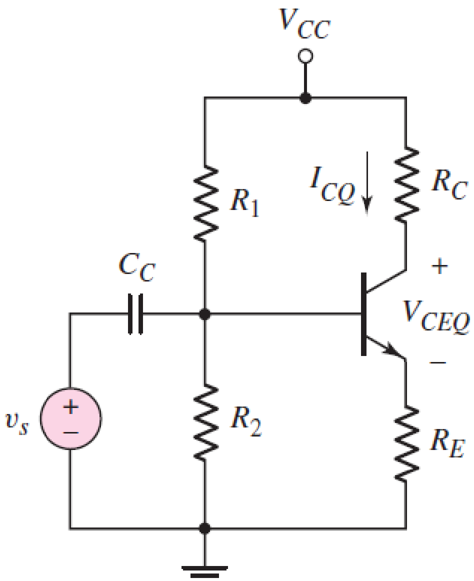


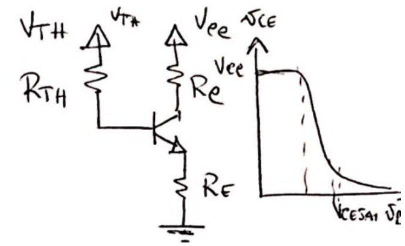
Figure 5.54 (a)

In addition sketch the input and output I-V characteristics and the input and output load lines.

In-class problem 1, solution



$$V_{CEQ} = \left|\frac{V_{CC} - V_{CESAT}}{2}\right| + V_{CESAT}$$



$$V_{CEQ} = \left|\frac{5-0.2}{2}\right| + 0.2 = 2.6V$$

$$I_{CQ} = \frac{V_{CC} - V_{CEQ}}{R_E + R_C} = \frac{5-2.6}{(1+0.2)k} = \frac{2.4}{1.2k} = 2mA$$

$$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{2m}{150} = 13.3\mu A \ (0.0133mA)$$

$$R_{TH} = (0.1)(1+\beta)R_E = 0.1(151)(0.2) = 3.02k\Omega$$

$$V_{TH} = \frac{R_2}{R_1+R_2}\cdot V_{CC} = \frac{1}{R_1} R_{TH} V_{CC} = \frac{1}{R_1}(3.02k)(5)$$

KVL on the input loop:

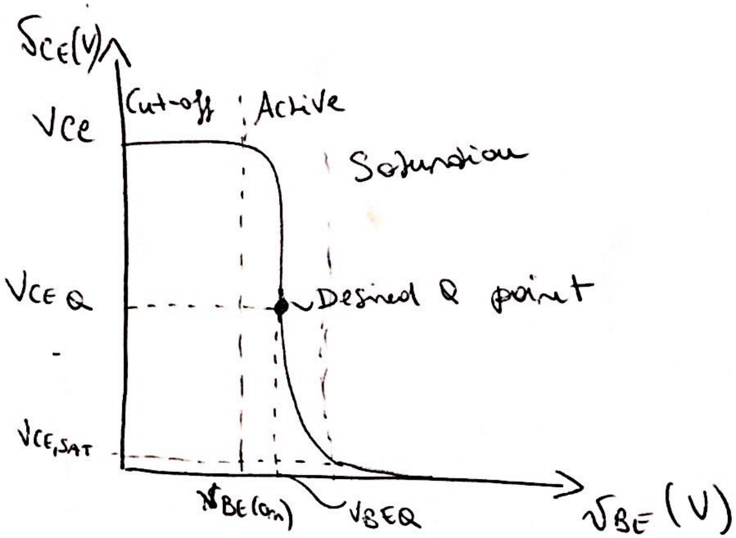
$$V_{TH} = I_{BQ} R_{TH} + V_{BE(on)} + \underbrace{(1+\beta) I_{BQ}}_{I_{EQ}} R_E$$

$$\frac{1}{R_1}(3.02k)(5) = (0.0133m)(3.02k) + 0.7 + (151)(0.0133)(0.2k)$$

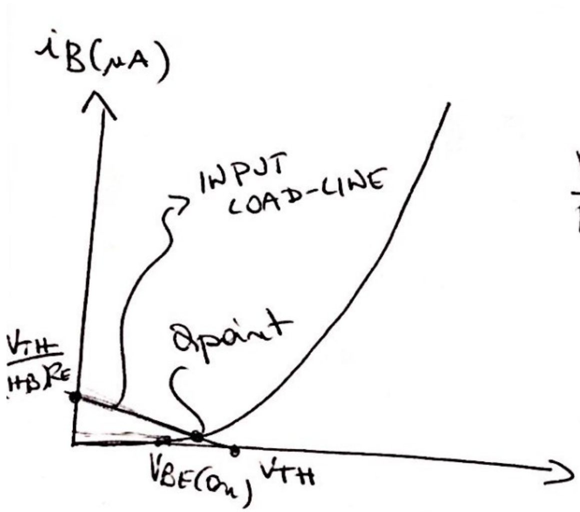
$$R_1 = 13k\Omega \qquad R_{TH} = \frac{R_1 R_2}{R_1 + R_2} = 3.02k\Omega$$

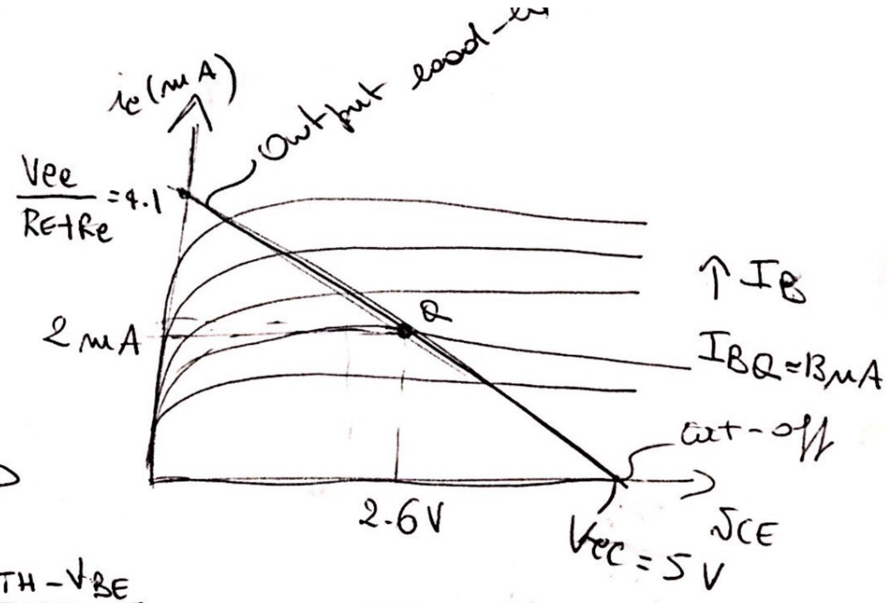
$$13k\Omega R_2 = 13k\Omega \cdot 3.02k\Omega + R_2 \cdot 3.02k\Omega$$

$$9.98k\Omega R_2 = 39.26M\Omega \Rightarrow R_2 = 3.93k\Omega$$



In-class problem 1, solution





$$I_B = \frac{V_{TH} - V_{BE}}{R_{TH} + (1+\beta) R_E} \simeq \frac{V_{TH} - V_{BE}}{(1+\beta) R_E}$$

$$V_{TH} = \frac{V_{cc} R_2}{R_1 + R_2} = \frac{5 \cdot 3.53K}{16.53K} = 1.16V$$

$$I_B = 0 \Rightarrow V_{BE} = V_{TH} = 1.16\ V$$

$$V_{BE} = 0 \Rightarrow I_B \simeq \frac{V_{TH}}{(1+\beta) R_E} = \frac{1.16}{151 \cdot 0.2K} = 38\mu A$$

$I_{BQ} = 13.3\mu A$ yields $V_{BEQ} \simeq 0.71V$

$$I_c = \frac{V_{cc} - V_{CE}}{R_E + R_c}$$

$I_c = 0 \quad V_{CE} = V_{cc}$

$V_{CE} = 0 \quad I_c = \dfrac{V_{cc}}{R_E + R_c}$

$I_B = I_{BQ} \simeq 13.3\mu A$

Overview of Lecture 13

- Biasing the BJT 2 (Neamen 5.2 and 5.4, S&S 6.7)